Digital Fitness Trainer (DFT)

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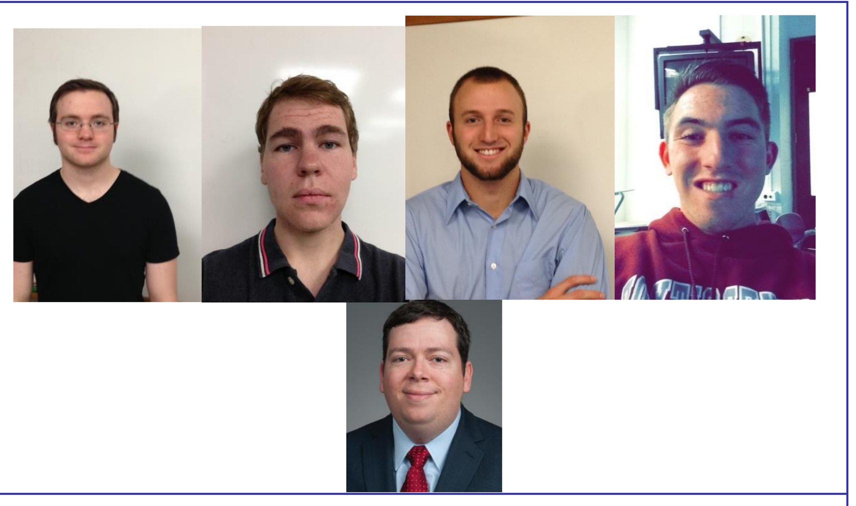

Abstract

DFT is a piece of exercise equipment combined with wearable technology that will allow users to perform free-weight strength training with a reduced risk of injury. Our system includes a Microsoft Kinect that is utilized by our software to look for signs of improper form, as well as a pair of compression shorts with surface electromyography (sEMG) probes and an embedded system. The Kinect will allow our software to warn the user when they are exercising incorrectly, and the shorts will allow the software to warn the user when their muscles are approaching the fatigue threshold. The combination of these sources of information will allow the DFT software to help users to reach their maximum potential during a workout while avoiding overexertion and improper form.

Block Diagram

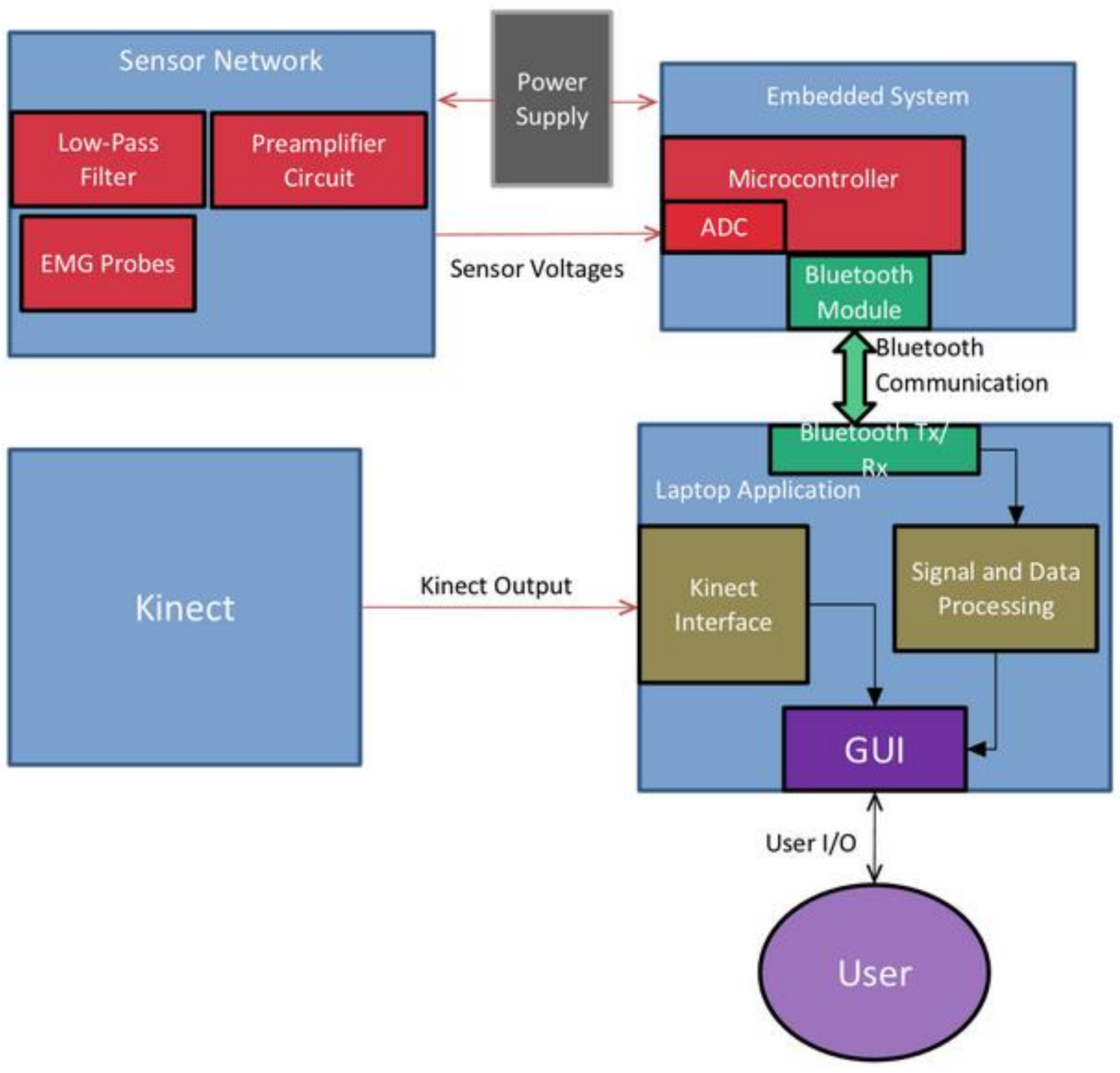

TABLE I
Specifications

Specifications

SPECIFICATION	Value
Sensors (EMG probes)	
Height	1cm
Length	1cm
Width	1cm
Embedded System	
Weight	<2lbs
Height	6.5cm
Length	11cm
Width	9.25cm
Battery Life	4 hours
Detachable	Yes
Kinect	
False Positive Rate	<5%
Bluetooth	
Maximum Distance	12 feet

System Overview

- Array of sensors embedded in athletic compression shorts
  - Electromyography (EMG) network under fabric
  - Comfortable for exercise
- Core module clipped to belt of shorts
  - Contains EMG sensor analog logic circuit and microcontroller
  - Provides Bluetooth communication with desktop application
- Kinect visual tracking
  - Accurate real-time tracking of form
- User Interface
  - Provides feedback on user form and estimated fatigue
  - Multiple exercises available for selection

Results

- Testing of the final prototype showed consistent tracking of user workout form. Feedback was accurate, with a maximum of one or two errors per set. Bluetooth communication, once an initial connection is made, is consistent and errors in transmission are extremely uncommon. The sensors are able to pick up signals on the major muscle groups, and the MPF given by signal processing is accurate to within +/- 4 Hz. The MPF decreases over the course of a workout, which indicates that fatigue is measurable by the system.

Acknowledgement

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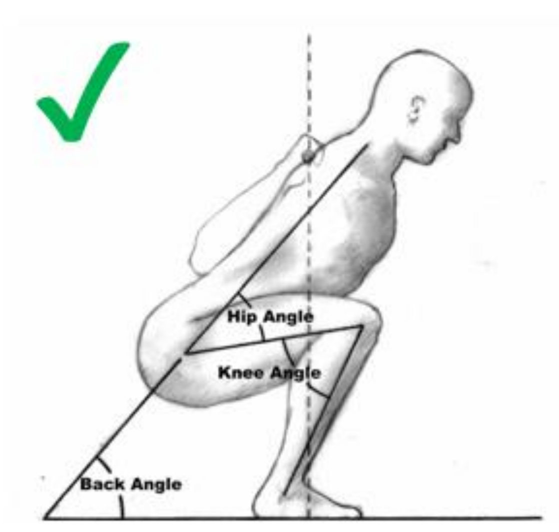
Sensors

- The sensors themselves are Electromyography (EMG) probes.
- The probes come in sets of two, which measure a differential voltage across a muscle which is caused by muscle twitches.
- There are six sets of sensors. One pair is on the quadriceps, another is on the gluteus, and the final pair is on the hamstrings.
- All the probes have a common ground which is located on the wearer's knee, an electrically neutral location.
- The sensors' output voltages are passed through low-noise amplifiers and low-pass filters to the input of the microcontroller's ADC.

Microsoft Kinect



- The Kinect includes a depth-sensing camera that is able to recreate a full 3D model of a human in real time.
- Joint and limb locations of the user are mapped to 3D coordinates from this model.
- Our desktop application uses this data to monitor for incorrect technique during the user's free-weight exercise movements.
- Specifically angles, relative locations, and movement coordination of the user's limbs are all analyzed to warn users of dangerous technique errors.

Cost

Development

Part	Price
Kinect	150
Microcontroller	2
Bluetooth Module	39
EMG Probes	150
Amplifiers	85
PCB	65
Total	491

Production

Part	Price
Kinect	150
Microcontroller	1
Bluetooth Module	14
EMG Probes	100
Amplifiers	40
PCB	13
Total	318

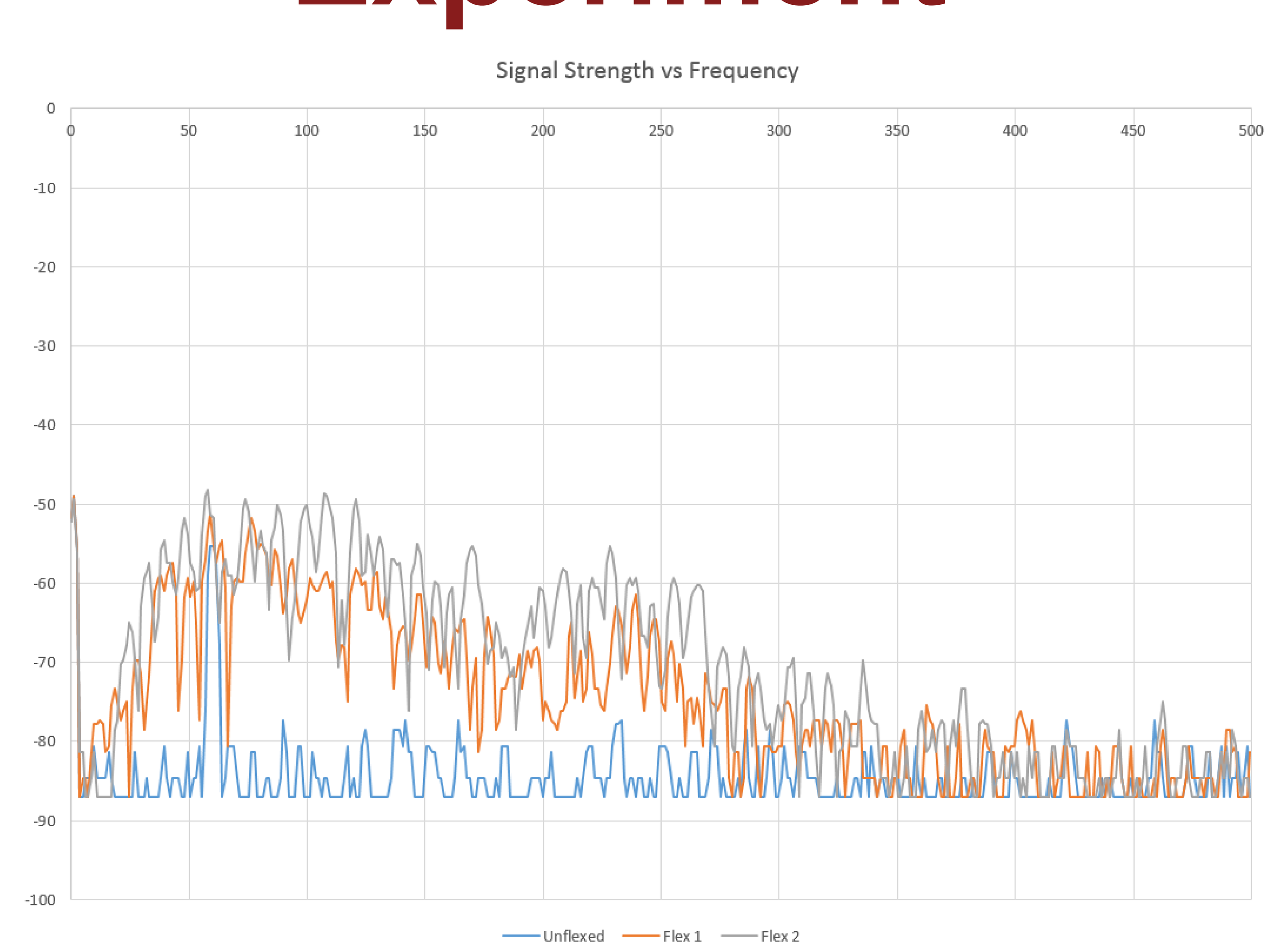
Embedded System

- The embedded system consists of a PIC32 microcontroller and a Roving Networks Bluetooth module.
- The embedded system is constantly communicating with the laptop and the sensors.
- When it receives a message from the computer, it takes 256 samples at 1 kHz from the sensor indicated by the computer and stores them in a buffer.
- As soon as it finishes sampling, the microcontroller sends the array of samples as a UART message to the Bluetooth Module, which sends them to the computer so it can process the data.

Signal Processing

- The signal processing portion of the laptop application is responsible not only for the signal processing, but also for Bluetooth communications with the embedded system.
- The signal processing and Bluetooth communication takes place inside a helper thread in the application, allowing the application to receive and process sensor data and Kinect data in parallel.
- The Bluetooth communication takes place using the Windows Bluetooth socket library.
- The computer sends messages to the embedded system to request data, and waits to receive the array of samples.
- When data is received, the helper thread runs a Fast Fourier Transform (FFT) algorithm on it to convert it to the frequency domain.
- The median power frequency (MPF) is found by sorting the frequency domain representation by power, finding the median power, and finding the frequency that matches that power.
- Each MPF is compared to the MPF from the start of the user's workout. When it reaches 70% of the original MPF, we say that the user is reaching the fatigue threshold.

Experiment



- We tested the output of the sensors on an oscilloscope equipped with a FFT function and compared the results obtained from the signal processing with the results given by the oscilloscope. We found that the MPF given by the signal processing thread was typically within +/- 4 Hz of the oscilloscope reading.